Investigation of Jovian Icy Moons Using *High-Powered* Radar Sounders

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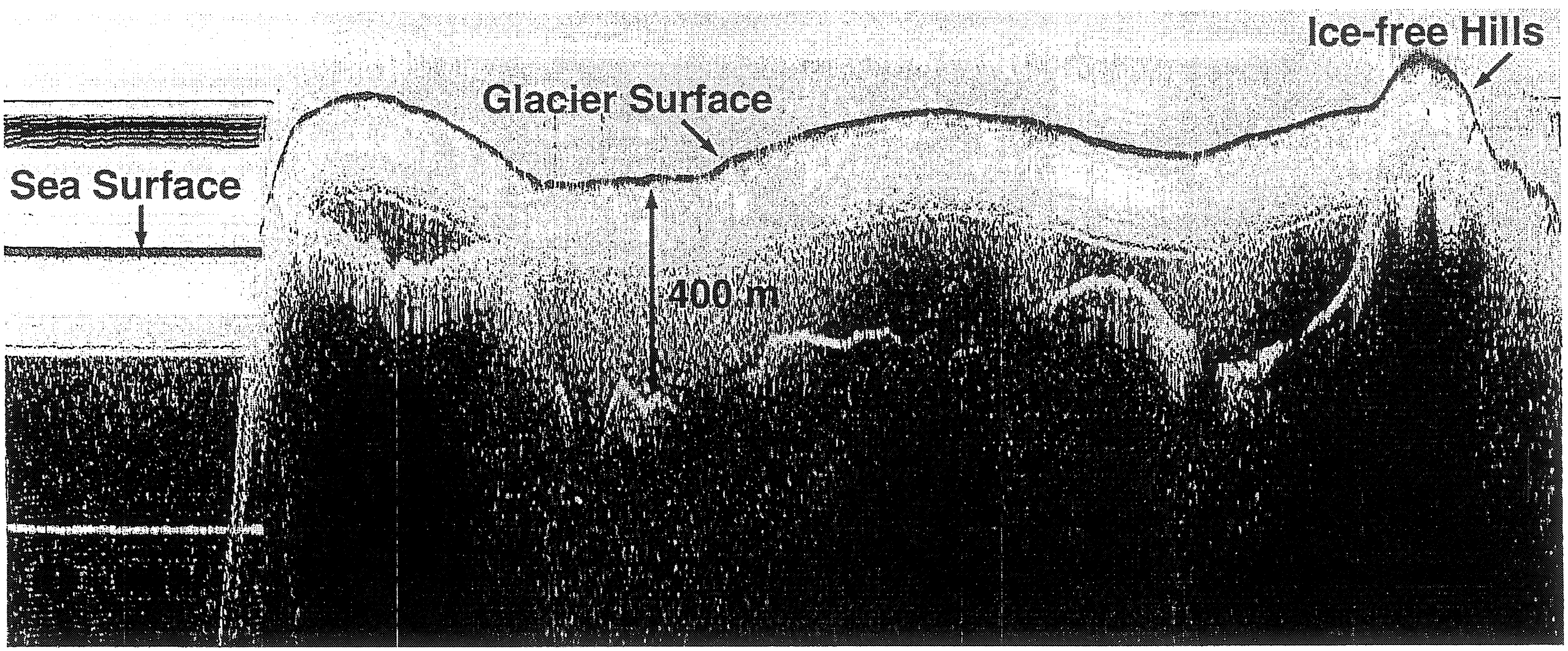
Radar Sounding

- Airborne radars have been used extensively to study glaciers and ice shells
- Other than ALSE, we have little experience with orbiting radar sounders
- Current missions include MARSIS (0.1-5.5 MHz) that is on its way to Mars and SHARAD (15-25 MHz) to fly on MRO, 2005.

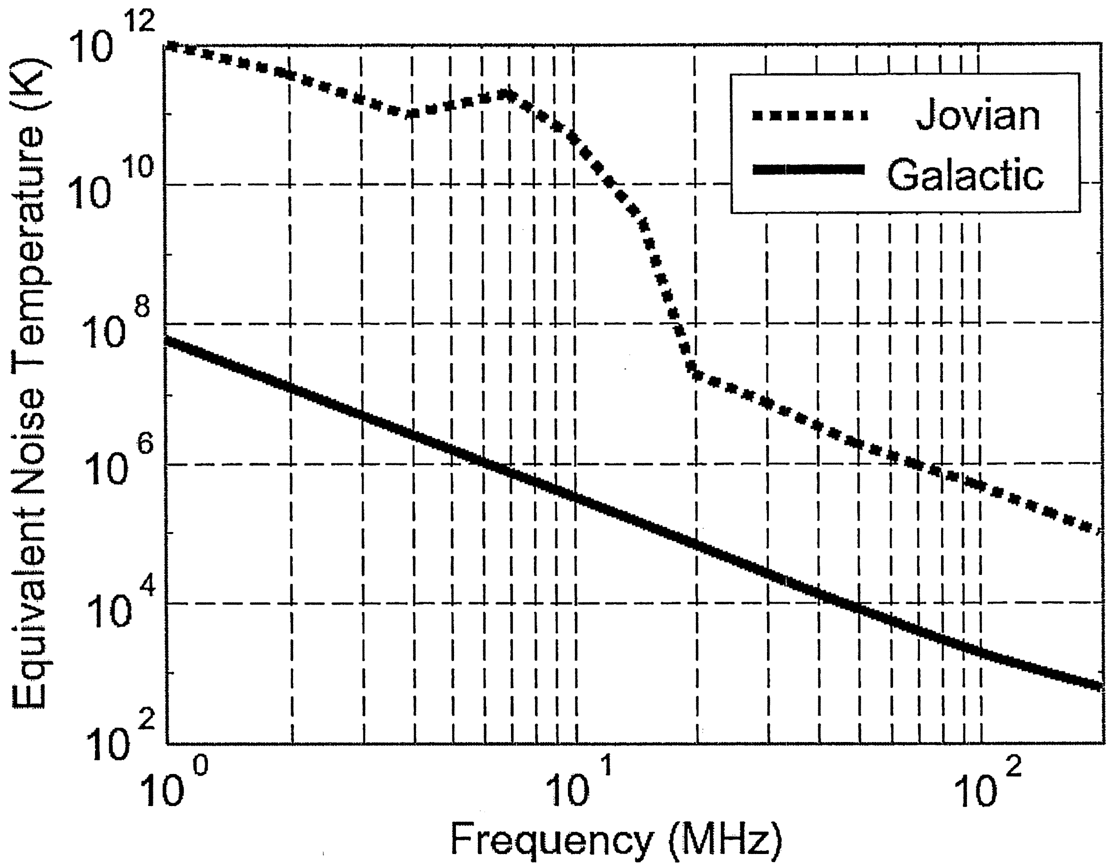
JPL/SOAR Airborne Radar Sounder
Wilson Piedmont Glacier, Antarctica, 2000



Major Design Parameters

- Attenuation/scattering property of the surface and the subsurface
  - Loss due to bulk medium attenuation
  - Loss due to volumetric scattering
  - Surface roughness
- Ambient noise environment
  - Galactic background noise
  - Jupiter noise
- Ionospheric limitations
  - Phase distortion
  - Attenuation
- Resource availability
  - Downlink capacity
  - Mass
  - **Power**
  - Antenna accommodation
  - Orbit design

Jupiter Noise Environment



*from Europa Orbiter IDT report, Blankenship *et al.* 1999

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Surface/Volume Scattering

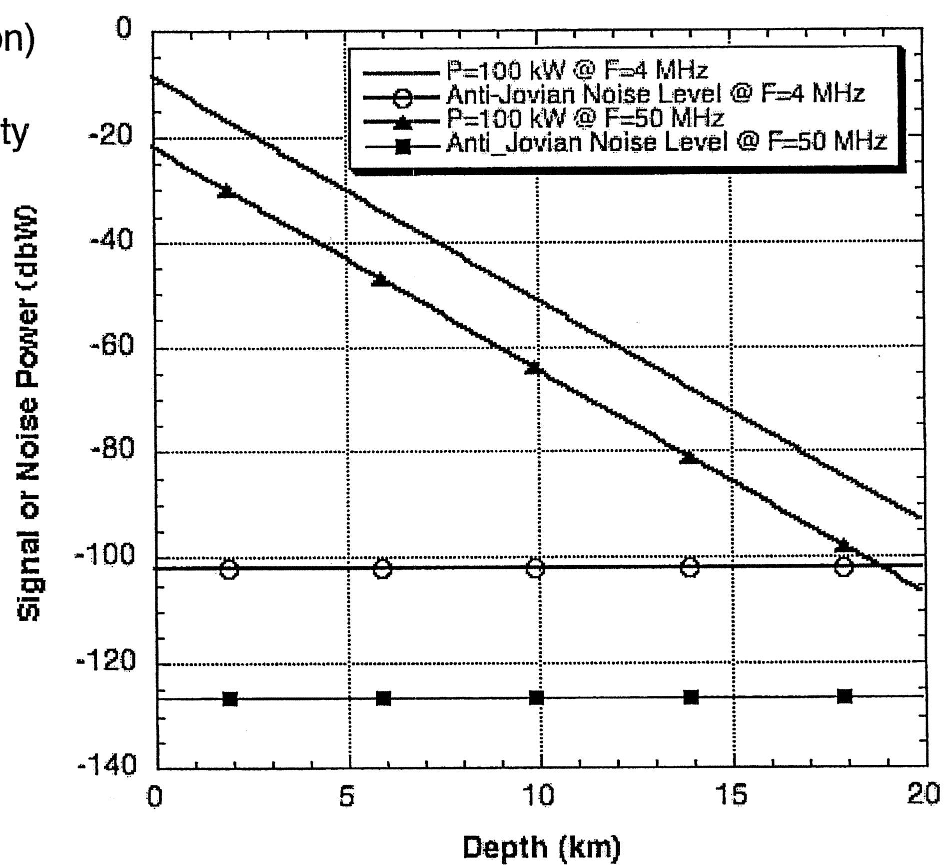
- Any surface scattering will result in clutter signal that will mask the subsurface signal
  - This problem can go away at lower frequency (e.g. < 10 MHz)
- Volume scattering can be caused by fractures and stratigraphy within the ice shell and can cause additional attenuation
  - This problem is alleviated by going to a lower frequency (e.g. < 10 MHz)

Choice of Frequency

- Reasons for choosing a higher frequency radar (e.g. 50 MHz):
  - Avoiding the Jovian/Galactic background noise
  - Increasing the radiated power in the direction of interest (through directive antenna)
  - The choice of 50 MHz over, for example, 4 MHz offers only a 10 db advantage.
- By taking into account the potential for attenuation and clutter due to surface and volumetric scattering, the low frequency option is clearly necessary.
- An alternative is to add a low-frequency band and take advantage of target body as a shield to block Jovian noise (in other words, operate in the anti-Jovian side of the target moon at the low-frequency band).

Radar Performance

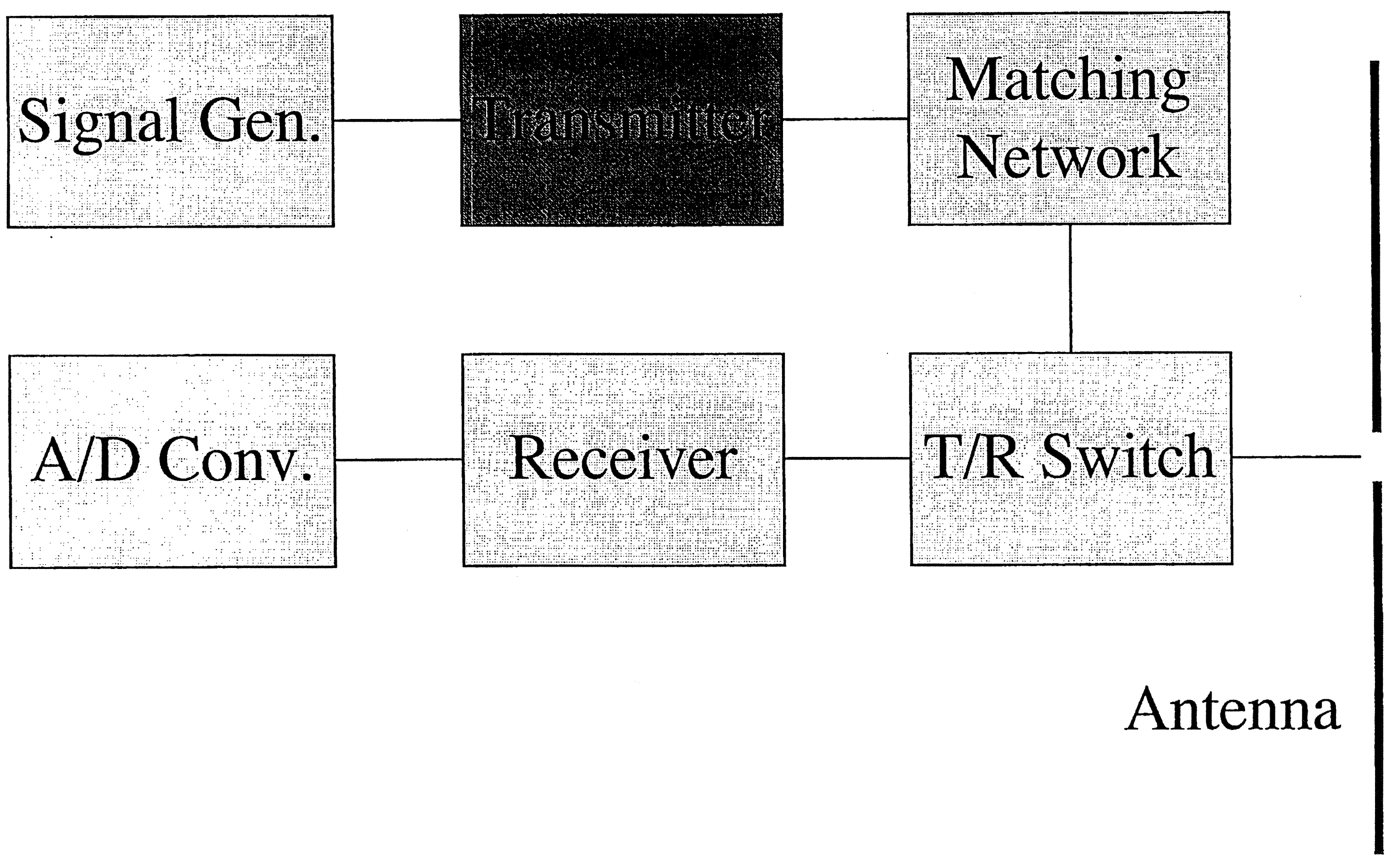
Attenuation: 4 db/km (two-way attenuation)
Corresponding to Marine Ice (Chloride dominated Europa ocean) 3.5 ppt chlorinity ocean
Surface temperature of 50 k
Base temperature of 270 K
Radar altitude of 100 km
Pulse length is 500 μ
Frequency is 4 and 50 MHz
Bandwidth is 2 MHz
Coherent integration over the Fresnel length
PRF is 375 Hz
Antenna gain of 10 db for 50 MHz
Antenna gain of 2 db for 4 MHz.



Radar Sounder Design Drivers

- If the detection of subsurface ocean is a major science objective, radar needs to be designed to maximize penetration depth by mitigating <u>unknown</u> risks as well as <u>known</u> risks.
- Key design parameters that improve the penetration are
  - Increasing radiated power (increasing signal)
  - Choosing the part of the EM spectrum where ice is most transparent under most expected scenarios (decreasing frequency)

Radar Block Diagram



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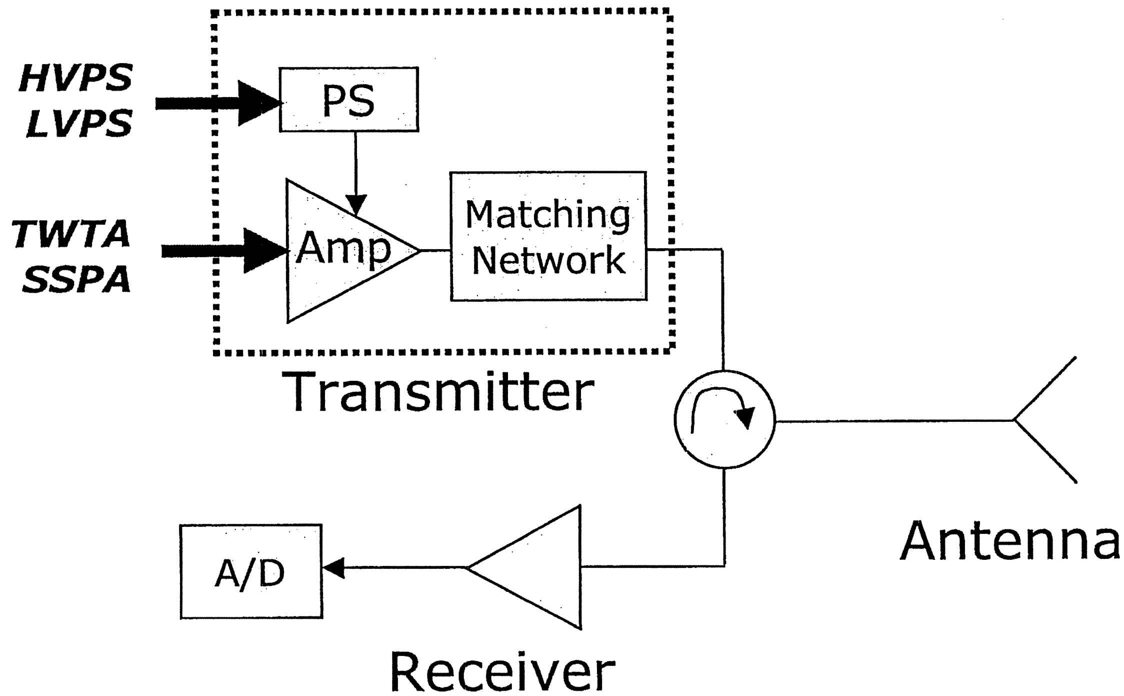
High-Power Technology Impact

- Currently, radiated power for spaceborne sounders is ~ 10 W (the case MARSIS and SHARAD).
- Using solid-state or vacuum tube technology, power levels as high as 10-100 kW can be achieved.
- An SNR improvement of 30-40 db or approximately doubling the depth of penetration

Radar Transmitter



Challenges of High Power Radar Instruments

- **Generating and radiating high transmit powers**
- Surviving high radiation environment
- Dissipating generated heat

Proposed Radar Sounder

- A high frequency radar (e.g. 50 MHz) as near surface, high-resolution mapper (Europa Orbiter design)
  - Provides higher resolution profiles
  - Better surface/near surface SNR in the Jovian side
- A low-frequency radar sounder (e.g. 5 MHz, "*high-powered MARSIS*") for deep sounding (e.g. 20 km)
  - provides maximum penetration with lowest risk at anti-Jovian side
  - Plasma wave sounding and passive plasma wave measurements